

**THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY**  
**Summary Report to NSAC**  
January 29, 2001

**Funding\***      **FY2000: \$73.0 M**                      **FY2001: \$73.4M**

**JLab Staffing<sup>+</sup>; FY 2000**

<u>PermPhd</u>	<u>PostDoc/Grad Stud/Undergrad</u>	<u>Tech/Adm</u>	<u>Total</u>
108	14      5      43	440	611

<u>Users</u>	<u>PhD Scientists/Grad Student/Undergrad</u>	<u>Total</u>
<b>FY2000</b>	<b>1253      225      65</b>	<b>1543</b>
<b>Percentage</b>	<b>81.2      14.6      4.2</b>	<b>100</b>

\* NP funding only; in 01 JLab received 21.0 from SNS, 8.0 for FEL , 1.4 from Virginia, and 1.0 in other funds

<sup>+</sup> Total lab staff, including non-NP-funded

**DOE/NSF/Other US/Foreign**

DOE and NSF primarily fund JLab users, with significant foreign participation. However, we have only just begun to collect data that would allow us to provide a detailed breakdown.

**Background**

The Thomas Jefferson National Accelerator Facility (Jefferson Lab) is a nuclear physics research laboratory run by the Southeastern Universities Research Association for the Department of Energy in Newport News, Virginia. Jefferson Lab is performing research that will increase our understanding of the structure of matter. Jefferson Lab serves an international user community of 1600, with 899 PhD scientists from 153 institutions in 26 countries on approved experiments. We have delivered about 50% of the currently approved experimental program, with 30 experiments complete and data gathered for substantial portions of 47 more in three years of full operation.

JLab is a leader in superconducting radiofrequency (SRF), a core technology that benefits not only Jefferson Lab but advances research and facilities in Nuclear Physics (Rare Isotope Accelerator) and Basic Energy Sciences (SNS, Next-Generation Light Source). Jefferson Lab also includes a Free Electron Laser (FEL) based on this core technology that has broken records for delivery of infrared light, and has been a valuable test bed for SRF development.

**Questions:**

- 1. What are the main new research initiatives which are being proposed for your facility during the coming years? Are there specific facility upgrades which you are pursuing to maintain the competitiveness of your facility through the next decade?*

The Nuclear Physics research program at Jefferson Lab is built upon major themes (or "Campaigns") that are coincident with the broad directions for the field identified in the 1996 Nuclear Science Advisory Committee's Long Range Plan and the 1999 National Academy of Science/National Research Council decadal survey. Each Campaign corresponds to an outstanding question in Nuclear Physics that is being addressed via a concerted program of experimental and theoretical work by Jefferson Lab's international university-based user community. These Campaigns are:

## **On the Structure of the Nuclear Building Blocks:**

*Campaign 1: Testing the Origin of Quark Confinement*

*Campaign 2: How Are the Nuclear Building Blocks Made from Quarks and Gluons*

*Campaign 3: Understanding the Origin of the Nucleon-Nucleon Force*

## **On the Structure of the Nuclei:**

*Campaign 4: Testing the limits of the Meson/Nucleon Description of Nuclei*

*Campaign 5: Probing the limits of the “Standard Model” of Nuclear Physics*

Jefferson Lab’s experimental program is in full swing in all three experimental halls and we have made remarkable progress in understanding the behavior of strongly interacting matter. These advances have revealed important new experimental questions best addressed at higher energies than the 4 GeV design specification developed for CEBAF at Jefferson Lab almost two decades ago. In fact, Campaign 1 and key elements of Campaign 2 above can only be addressed at higher energy. Fortunately, favorable technical developments coupled with foresight in facility design make it feasible to triple CEBAF’s beam energy from the initial design value of 4 GeV to 12 GeV (doubling the achieved energy of 6 GeV) in a very cost-effective manner: the Upgrade can be realized for a modest fraction of the cost of the initial facility, enabling CEBAF’s world-wide user community to greatly expand its research horizons and maintain leadership in this critical field. The proposed upgrade allows breakthrough programs to be launched in two key areas:

- *The experimental observation of the QCD flux tubes which cause confinement.* Theoretical conjectures, now confirmed by lattice QCD simulations, indicate that the most spectacular new prediction of QCD – quark confinement – occurs through the formation of a string-like “flux tube” between quarks. This conclusion (and proposed mechanisms of flux tube formation) can be tested by determining the spectrum of the gluonic excitations of mesons.
- *The measurement of the quark and gluon wavefunctions of the nuclear building blocks.* A vast improvement in our knowledge of the fundamental structure of the proton and neutron can be achieved. Not only can existing “deep inelastic scattering” cross sections be extended for the first time to cover the critical region where their basic three-quark structure dominates, but also measurements of new “deep exclusive scattering” cross sections will open the door to a new, more complete characterization of these wavefunctions by providing direct access to information on the correlations among the quarks.

In addition to opening up these qualitatively new areas of research, the Upgrade will open important new research domains in key areas already under investigation. These new research thrusts include:

- Determining the dynamics underlying the quark-gluon wavefunctions through measurements of the high-momentum-transfer behavior of form factors.
- Mapping out and understanding the transition from the hadronic to the quark-gluonic description of strongly interacting matter through the study of low-energy duality.
- Searching for the onset of color transparency effects in the region where they are supposed to exist.
- Determining the role of color polarization effects in the  $NN$  force by measuring the threshold  $_N$  cross section
- Executing a unique and global study of short-range correlations in nuclei.
- Examining the role of quark masses in determining hadron spectra by mapping out the currently obscure  $s\bar{s}$  spectrum that straddles the boundary between the rigorously understood heavy-quark systems and the poorly understood light-quark world.

This upgrade is not only important to completing the picture begun with our current experimental program in Nuclear Physics, but the R&D in SRF and expertise in related technologies that enable it are critical for many of the facilities underway or planned in the larger DOE science community. The 12 GeV

upgrade is a \$150M project, with \$120M sought from DOE and JLab could begin as early as 2003, with construction complete in four years.

2. *The LRP Charge to NSAC explicitly asks us to consider the FY 2001 Budget as the baseline budget for the field. Is this, in fact, a budget level which will allow your facility to operate in a lean but competitive and cost-effective manner, in the years to come? If not what are the essential additional resources which you would require and the benefits that would accrue from them?*

Jefferson Lab's present operations budget would need to be increased by about \$10M to address key problems including: effective, efficient operations and facility utilization; required staffing in key science areas; enhanced theory support of JLab/MIT lattice QCD initiative; SRF basic and applied research; and lagging staff salaries relative to competition from industry in high-tech specialties. JLab has been in full operation (all three halls, all accelerator capabilities) for FY '98, '99, '00, and is now in its 4<sup>th</sup> year. The October '98 Medium Energy Review concluded that JLab operation was the highest priority in the field, that 32 weeks /year at 75% availability was desirable, and that the cost for this effort, including steady improvements to machine availability, higher energy running, and improvements to user space would amount to FY'98 + inflation + \$3M. Actual facility operations funding has lagged this goal by \$1.6 M in FY99, \$2.1 M in '00, \$1.5 M in FY '01 PB, and \$ 2.8 M in FY '01 actual allocation. JLab has, in those years, given highest priority to running the approved program following the scientific merit assigned by the PAC, and making the prerequisite machine and equipment improvements, particularly in polarized beams and higher energy running. It also has, through creative arrangements via excellent relations with the City of Newport News, provided urgently needed space for about 200 users.

As a consequence, minimal resources were available in other areas and JLab continues to have critical unmet needs requiring additional funds (\$10M). These needs include: 1) improvements of physics productivity to reduce a backlog of 4 to 5 years to a more acceptable 3 years in all halls through improved availability, higher multiplicity, and longer running, achieving higher polarization, and reliable 6 GeV running, resulting in an increase of at least 25 % in physics throughput (\$2.1M), 2) increased staff at the leadership and support level in the Physics Division to sustain current productivity and ensure the highest quality and rapid dissemination of results (\$2.3M). This would include support for the theory effort, as well as some modest investment (\$1.0M) in computer hardware in the context of the MIT-JLab lattice QCD collaboration. Also, in providing beam to users as our highest priority, Lab salaries have been raised only modestly, resulting in a critical need for adjustments in selected categories (IT, EE) (\$1.1M).

Some investment in our core competencies is also called for. For a timely and cost-effective start of the 12 GeV upgrade, JLab has to strengthen its prototyping effort, which will benefit not only our upgrade but is synergistic with our SNS and RIA contributions (\$3.0M). Also, independent of any specific project, JLab has unique capabilities both to advance the state of the art in SRF technology, and to mature the technology from being an "art" to solid scientific foundations, and therefore predictable and reproducible results (\$.8M).

While the breakdown of the additional funds needed may change over time, we anticipate that this total level of operations funding (FY01 + \$10M) is required for the productive and sustainable operation at 6 GeV.

3. *What is the balance of your research program between work at your local facility and outside user efforts at other facilities in the US or abroad? Has this balance changed since the last LRP, and do you expect it to evolve further in the coming years?*

Research staff at Jefferson Lab predominantly provides support to the user program, with < 25% of their time available for in-house research (none of our scientists perform research at other facilities). Recent peer review committees have recommended and our experience has shown that this level of research time is not adequate to keep our best and brightest scientists. Unfortunately, at the FY2001 budget level we cannot relieve our scientific personnel to increase the fraction of their time spent in research.

*4. Are you satisfied with your ability to attract and support top quality graduate students?*

Jefferson Lab is a user facility; therefore graduate students are involved with the lab via a university-based user program. We have worked very hard at building a core of universities both locally and throughout the Southeast via joint and bridged positions in order to attract bright graduate students in Nuclear Physics. Sixty-eight PhDs based on JLab research have been completed over the past three years, and 156 PhD students are currently pursuing thesis projects based on JLab research.

*5. Are there other aspects of your facility and programs which are unique or particularly noteworthy?*

Jefferson Lab's capabilities are unique worldwide and most likely will remain so. There is simply no competition for JLab's combination of available energies, from ~.8 to 5.7 GeV, and luminosity,  $10^{34}$  to  $10^{39}$  cm<sup>-2</sup>s<sup>-1</sup>, beam emittance <1 nm, energy spread  $\sim 10^{-4}$ , and simultaneous operation of three halls with currents from 100 pA to >100  $\mu$ A. Equally important is the availability of beams with polarization in excess of 75% at currents exceeding 100  $\mu$ A, and with minimal helicity correlated variations of beam parameters, making them ideally suited for precision parity violation experiments. JLab is now the center for strong interaction physics with electromagnetic probes, and with the 12 GeV Upgrade, will remain so well into the future.

In accelerator technology, JLab is at the cutting edge in several areas of significant impact, including SRF technology and related beam physics of beam cavity interactions, 2 K cryogenic technology, and the generation of high-brightness polarized (and unpolarized) electron beams. The JLab FEL has served as a test bed to gain more detailed information on beam cavity interactions and the higher-order-mode spectrum of SRF cavities, has allowed a degree of experimental verification of models of coherent synchrotron radiation, and most importantly is the first demonstration of the feasibility of building and operating energy recovering linacs (ERLs). JLab applies its capabilities in these areas by contributing to RIA R&D and building the SNS linac. In addition JLab's accelerator expertise and at least two of its core competencies are invoked in proposals for high energy electron cooling (RHIC's luminosity upgrade), Electron Ion Colliders, and next generation light sources.

Jefferson Lab enjoys excellent community relations at the local and state level as evidenced by the state funding of the FEL building and the city-funded 7-story office-lab complex built on our campus.